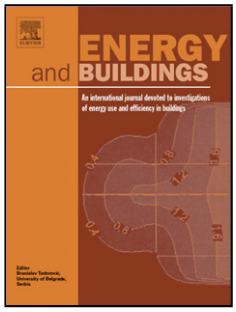

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What are the factors that discourage companies in the Irish commercial sector from investigating energy saving options?

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Highlights:

- Logit models applied to representative data of Irish Commercial sector
- Factors associated with the investigation of energy saving option determined.
- Tenants who lack decision-making power significantly less likely to investigate.
- Providing floor area m^2 associated with higher likelihood of investigation.
- Commercial activity, employees, budget rules, payback and renovations significant.

Abstract:

This paper examines the barriers and drivers at the first step in the process in the implementation of an energy saving measure, the investigation step. The representative survey data shows that almost half of Irish companies operating in the commercial sector do not take this first essential step. Two Logit models are fit to the data. The influence of variables, representing company and building characteristics, on the likelihoods of a company investigating either a fabric upgrade or a behaviour change energy saving measure are assessed.

Keywords: energy efficiency; Commercial sector; barriers; logit model;

Companies are more likely to investigate a fabric upgrade that: own the building they operate from, make energy related decisions locally, have more than 10 employees, have had a recent renovation, accept longer paybacks, and apply a case by case approach to budget decisions. Hotels and offices were found to have a higher likelihood of investigating fabric options. Lack of knowledge of building floor area reduced the likelihood of investigation of both fabric upgrade and behavioural options. Much of the previous research is concerned with the final adoption of measures; this analysis adds additional insights by identifying the factors that determine if a company is likely to investigate the options available.

1. Introduction

The International Energy Agency has shown that action to increase efficiency can halve energy demand growth to 2035 [1,2]. Unlocking this potential is a key policy challenge facing governments' efforts to reduce greenhouse gas (GHG) emissions [1,3,4]. Along with the direct climate and energy cost reduction benefits, energy efficiency has been shown to deliver tangible co-benefits for nations, industry, businesses and individuals [5]. These include improved security of supply, higher productivity, GDP increases, less exposure to fuel price volatility, increased comfort levels in buildings and improved human health outcomes.

The services sector is not a large consumer of energy, even in economies where the sector is responsible for the majority of economic activity. The services sector includes both

commercial[1] (comprising banking, retail, hotels, etc.) and public (education, health, local government, etc.) services. Energy use in the services sector represented 13% (5,911 PJ) of final energy consumption in the EU in 2014 [6]. In comparison, transport (14,755 PJ), industry (11,505 PJ) and residential (11,019 PJ) sectors have much higher annual energy demand. Future energy projections suggest that the services sector is likely to maintain that share [7].

Analyses of the energy savings potential however, indicate that the commercial sector has significant potential to reduce energy consumption [8–10]. Ecofys and Fraunhofer ISI (2010) examination of the marginal savings curve for energy efficiency investments shows that energy efficiency investment in the services / commercial sector offers some 100 Mtoe (4,187 PJ) of savings (~25% of total potential savings available in all sectors) [8]. This confirms earlier analysis conducted by Fraunhofer ISI et al., for the European Commission that found the tertiary sector holds 22% of the total savings potential to 2030 across all sectors [9]. Almost half of these savings come at a negative cost if the necessary policy instruments act to remove the barriers to investment in energy efficiency measures. Analysis of the energy efficiency potential and costs in Ireland shows similar results [11].

In Ireland, the commercial sector accounts for 7% of final energy consumption but 11% of the total primary energy requirement. The relatively high proportion of electricity use in the Irish commercial sector drives the higher share of primary energy [12]. Projections for the Irish energy system show that the sector is likely to increase its share in final energy demand to 13% [13]. The service sector in Ireland accounts for 70% of GDP, 54% of all active companies (EU average is 45.5%) and employs 51% of the working population [14]. In addition, the sector is one of the largest indigenous exporters and competitiveness is a key concern [15]. The technical potential for energy savings in the Irish commercial sector represents 26% of the total available across all sectors to 2020. The value of the savings available over the full lifetime of most measures are greater than investment costs for these measures i.e. negative cost over the full lifetime [11].

The observation of a gap between the actual uptake of energy efficiency measures and the economic potential predicted by engineering-economic models is common in the literature on energy efficiency. A body of theoretical and empirical literature has explored the barriers contributing to this phenomenon. Using representative survey data from Ireland, this paper aims to identify the characteristics of commercial companies that are likely and unlikely to engage with energy efficiency actions in the context of the barriers to, and drivers of, energy efficiency. Two distinct categories of measures are possible for companies to implement: behavioural measures that lead to changes in how employees use and conserve energy, (e.g. reducing room temperature or turning off appliances when not in use); and building upgrade measures (e.g. insulating walls, installing lighting controls or a more efficient heating source). Two separate logit models are fit to the data on relevant factors including company activity, number of employees, tenure, building size and stated approach to financial

[1] The commercial sector is defined as all business related *non-residential* activities outside of manufacturing, transport, public services and non-governmental organisations

decision making. This adds to the limited empirical evidence on energy efficiency in the commercial sector and contributes new information on the factors that discourage companies from engaging with the available energy saving opportunities. Representative data on energy use and attitudes in the commercial sector are rare and the data set that underpins this analysis is notable as being representative of the Irish commercial building stock and the attitudes of commercial sector companies to energy efficiency actions.

Section 2 provides an overview of the literature. A full description of the data, the model specification are included in Section 3, Section 4 presents the results, Section 5 discusses the key insights in the context of the relevant previous empirical research and Section 6 concludes.

2. Literature background

The difference between the actual level of energy efficiency action and the rate implied by these models has been labelled the 'energy efficiency gap' [16–18]. Theoretical investigations into of the causes of the gap have shown that a range of barriers to investment exists in commercial organisations. Sorrell [19], is a key reference that has identified and categorised the barriers to energy efficiency into economic, behavioural and organisational. Economic barriers include market failures like imperfect and asymmetric information, adverse selection, principle agent relationships subject to moral hazard, split incentives and heterogeneity [17,20–25]. Non-market failures also present barriers in the form of hidden costs, uncertainty/risk and access to capital [17,26–28]. Human behaviour barriers such as bounded rationality in decision-making, trust and credibility, the form and timing of how information is communicated, resistance of consumers to change (inertia) and the personal values of decision makers have been shown to diminish the uptake of energy efficiency technology [23,28–33]. At the organisation level the power or status of divisions and/or individuals with responsibility for energy decisions and how conservation and environmental issues are viewed in the organisational culture can act as barriers to uptake[19,24,34–40]. In practice these barriers overlap and energy related decisions in a commercial organisation will have aspects of economic, behavioural and organisational barriers[40,41].

The literature on the drivers for energy efficiency in the sector is less developed. Reddy and Assenza [42] and Cagno and Trianni [43] list the drivers of energy efficiency that also includes energy management practices as well as energy efficient technology. The classification of drivers lists management sensitivity to environmental issues, external pressures on the bottom line from rising fuel, CO_2 prices or other regulatory penalties, having clients who consider environmental behaviour in decisions, and having access to information from case studies of interventions by similar companies. Additional drivers include access to low cost expert advice (particularly for small companies), internal competence in energy management, availability of public financing, a focus on long term benefits, availability of new solutions, anticipation of environmental regulations and an entrepreneurial culture within the company. The literature on business engagement with wider environmental issues report similar classifications of drivers [44–46].

The empirical literature has used a number of methods to investigate the impact and importance of the barriers to energy efficiency in practice. These have examined barriers in the industrial sector, small and Medium Enterprises (SMEs) and various sub-sectors within

this. Given the relatively low number of empirical analyses and lack of studies that examine the commercial sector in isolation, all relevant studies are considered here.

A number of case studies, based on interviews with smaller sample of companies, have provided insight into the energy related decision-making processes within organisations [33,37,47–49]. Econometric and other statistical analyses, based on larger data samples, have sought to establish the significance and importance of the barriers and company factors that impede uptake of energy efficiency [19,38,39,50–63]. Sorrell et al. [64] and Fleiter et al., [62] contain detailed literature reviews of the various empirical studies on the barriers to energy efficiency. Both reviews point to the difficulty in comparing results across studies due to the different methods employed and the variations, time horizons, sectors and sub sector examined and the barriers considered. Nevertheless some noteworthy results have been identified.

Sorrell et.al [64] assessed the relative importance of the barriers based on a simple count of the barriers identified in the empirical research on energy efficiency in the services sector. The findings identify differences between developed and developing countries. Imperfect information was the most identified barrier in developed countries with access to capital the most frequently identified in developing countries. Hidden costs, risk/uncertainty and bounded rationality were also identified frequently. The review points to the greater obstacles faced by SMEs. Sorrell et al. [64], suggest that this is due to a lack of information about the opportunities available and a lack of implementation expertise where opportunities have been identified. The costs of obtaining relevant data on energy consumption is relativley more expesive for SMEs and energy costs typically account for a small proportion of total production costs. The high option cost of a large capital investment for SMEs hightens the sensitivity to the risk and uncertainty surrounding captial investments.

Fleiter et al. [62] comphrensive review of previous empirical litriture shows that SMEs tend to face more barriers to the implementation of energy efficient measures than their industrial counterparts. The most common barriers being access to capital, and for energy intensive SMEs, the technical risk associated with a production outage. In less energy intensive SMEs, the lack of time and lack of information show up as significant barriers to energy efficiency. Other frequently identified factors were the number of available employees, bounded rationality and split incentives.

The relevence of the emprical literature in informing the specfication of model used for our analysis is described in more detail in section 3.

3. Data and Methods

3.1. Data

In recognition of the data and information deficit in the commercial sector – and the difficulties it causes for effective policy making – the Sustainable Energy Authority of Ireland (SEAI) recently undertook a survey of energy use in the commercial sector and the attitudes of commercial sector companies to energy projects [65,66]. This data set is notable as a statistically representative dataset of the commercial building stock and the attitudes of commercial sector companies to energy efficiency actions.

A total of 750 phone interviews were conducted in March 2014 across a statistically representative sample of commercial business activities in Ireland. The survey collected data relating to the behaviour and decision-making process of commercial sector companies as well as physical information on their buildings.

Figure 1 shows the primary and final energy use estimated from the building survey data, broken down by fuel and by commercial activity categories. Electricity accounts for 73% of final energy consumption. The conversion losses in generating electricity are greater than for other fuel sources and about 2.5 units of primary energy are required for each unit of electrical end use, electricity accounts for 86 % of the 70 PJ of primary energy used in the commercial sector.

Table 2 summarises the survey information collected in more detail showing the frequency of the responses by business activity type. The sampling method across the sectors is calibrated against the distribution of business types recorded in the Geodirectory – a database of all commercial business active in Ireland – to provide a statistically representative sample of business types [65]. There are some notable differences in the distributions across the business types for several variables. For example hotels and restaurants/public houses tend to be owned by the occupant while retail premises and offices tend to be rented. Similarly, the proportion of companies within a business sector where energy related decision-making responsibilities reside within the business unit, are notably higher for hotels and public houses than in other business activity areas.

Differences are also evident across the types of fuel used for heating and building size and retail business and restaurants/public houses have a relatively high percentage of business with less than 10 employees.

Overall, the majority of organisations report having considered either behaviour or a fabric upgrade measure. A large proportion of those companies who said they have investigated a measure consider themselves to have done everything that is possible . This category may well be less engaged in the future and are not aware that significant potential likely remains. Half of the retail and warehouse companies surveyed reported not having investigated fabric upgrade measures and over 40% of the same categories have not investigated the savings available through behavioural measures.

Figure 2 shows payback period that a company is willing to accept on an energy related investment for each business activity. More hotels are willing to accept a longer payback on investment than is the case in the other commercial activities.

Respondents who stated they had not investigated an energy efficiency upgrade were asked the follow up question: what was the primary reason for not investigating a measure? The respondents could choose from four options for behavioural measures and five for fabric upgrades. The fabric upgrade choices were: “a) we do not think we need to reduce our energy use is a top priority, b) we do not think there are any ways to reduce our energy use c) we think there are ways to reduce but need more information d) we think there are ways to reduce but it’s not our responsibility e) we are planning to investigate in the near future.” These reasons are summarised in Table 3 and provide a context for the model results presented in the next section. A full description of the survey and results is available from [66]. The low priority of energy is the primary reason reported by commercial organisations

for not engaging with energy efficiency. Lack of information and lack of trust in the savings available are also reported frequently as the most important barrier.

3.2. Model

As companies who do not investigate potential energy efficiency measures cannot deliberately implement energy efficiency actions, the data suggests a selection bias problem – i.e. only those companies who have investigated will implement a measure. Initially a heckman selection model was fitted to the data in an effort to control for selection bias. For both the behaviour change measures and fabric upgrade models there was no statistical support for a selection bias and consequently we proceeded with a standard logit model

Two separate logit models are estimated to examine the factors that discourage engagement with behaviour change measures and the factors that discourage investigation of building fabric upgrade options. Both models include variables that describe building specific and business specific characteristics of the respondents. The dichotomous dependant variables are equal to 1 if a business investigated an energy efficiency measure. [2]

The explanatory variables included in the regression equations are guided by the findings of previous empirical analysis from the literature on barriers to energy efficiency, discussed further below. The general model specification is as follows:

$$\Pr(Y_{i,j} = 1) = \frac{1}{1 + \exp(f(Z_{i,j}, X_{i,j})}$$

where Y_i =1 if the company has investigated a fabric upgrade measure and Y_j =1 if a company has investigated a behaviour change measure. Z captures the company specific factors like business activity, tenure, number of employees and approach to financial decision making while X refers to the building specific factors like floor area, fuel used for heating and recent renovations.

Access to capital both internally within a company and though external sources has been frequently identified as an important barrier in previous empirical research [39,47,50,53,67,68]. The BUDGET variable captures the impact of capital restrictions by differentiating between companies that have fixed maximum budget amounts and those companies consider the business case for each measure on its own merits. Bounded rationality in financial decisions has also been found to influence energy related decision making [33,57]. In order to capture this, the BUDGET variable categorises companies into those companies that apply fixed budget rules (i.e. they will not consider a project above a certain pre-defined costs) and those that implement a business case approach for projects.

[2] Multinomial logit models were initially fit to the data that divided the dependent variables into companies that investigated behavior change, companies that investigated fabric upgrade, companies who looked at both fabric and behavior and companies who did neither. It was found that they were unsuitable due to the sample size leading to lack of data required to assess the interaction of independent variables within sectors.

The *a priori* expectation is that fixed budgets will impede engagement with energy efficiency options.

PAYBACK requirements also reflect bounded rationality barriers and captures uncertainty and risk considerations. Uncertainty and risk have been identified in previous empirical analysis as a primary barrier to energy conservation[50,51,54,59,62,68]. A positive coefficient sign is expected as the longer a company is willing to wait for a positive return, the more likely they will consider an energy efficiency investment.

The number of EMPLOYEES may positively impact on the expertise and time available in the organisation to investigate the options for energy saving measures. A company with less employees may face higher hidden costs in gathering the information required to implement an energy efficiency project [19,37,39,50,52,53,61]. Companies with more employees may have a higher availability of time and expertise and hence more opportunities to engage in research of energy efficiency options. Companies with larger number of employees may also suffer negatively form organisational barriers like complex decision making chains, status of energy and strategic value of energy projects and principle/agent and split incentive barriers that occur in lager organisations[19,49,52,53,58]. Given these potentially opposing effects no *a priori* expectations on the sign of the coefficient where established.

The DECISION_MAKER variable also captures some organisational barriers. Companies where energy decisions occur at the business unit level maybe more likely to have investigated and implemented energy efficiency measures as they have more ownership over the outcome and may see more of the resultant energy cost saving benefits, comfort and other benefits. Hence a positive coefficient is expected. The OWNER variable captures the barriers of split incentives and principle/agent moral hazard between landlords and tenants. If a company owns the building the building from which they operate, they will reap the full benefits on any investment in building upgrades hence a positive estimated coefficient is anticipated. The interaction of these variables is also likely to have a positive influence on engagement with energy efficiency.

Building specific variables include the energy source for heat energy (ELECTRICITY) and the floor area of the building (M2). Companies with large floor area and companies who use electricity as their main heating fuel are likely to have more expensive energy bills but may also have lower per unit energy prices as a result of the pricing tariffs of energy suppliers. It is expected that larger buildings and buildings with more expensive heat sources are more likely to investigate energy demand reduction options. The M2 categorical variable includes responses with no information. This may imply a lack of awareness of the built environment a company is operating from; if basic information like floor area was not provided then it may be likely questions on the less obvious information like type of lighting or the u value of the walls would also go unanswered. For this cohort, the expectation is that the estimator will have a negative relationship to the likelihood of investigating an energy efficiency measure. The 'lack of information' barrier has frequently been identified in previous empirical studies [38,52,56,61,62,69].

A cohort of respondents did not reply to the survey question on floor area. This cohort can be said to be missing at random (MAR) as the lack of response is likely related to some observed characteristics of the company and building but this does not depend on that organisations' overall attitude to energy efficiency opportunities. To examine how this impacts on overall engagement with energy efficiency and how this information barrier may

impact engagement three separate methods are used to estimate the logit models 1) The No Reply cohort from the survey data is estimated as a category in the M2 variable, 2) with the list wise deletion of the No Reply observations and 3) with multiple imputation of the No Reply using the Multivariate Imputation by Chain Equations (MICE) method as described by [70–73].[3] The listwise deletion can provide some insight into how firms who have provided basic information about their building engage with energy efficiency options relative to those who did not provide basic information on floor area. The Multiple Imputation model re-categorises the 'no reply' respondents into large buildings (floor area > 1,000m^2) and small buildings (floor area < 1,000 m^2) based on the imputed likelihood that the fall into either category based on the observed relationship with other survey variables.

Premises that have had some form of building RENOVATION may be more aware of the options for energy efficiency as a natural consequence of engaging with building contractors with knowledge of energy efficiency technologies and the requirement to consider the wider impacts of building related design decisions. Fleiter et al., [62] show that information provided to companies though energy audit programme in Germany have resulted in increased awareness of energy consumption.

The business ACTIVITY variable controls for implicit information on the sub-sector specific barriers that impact on energy efficiency decisions. Some empirical evidence has shown that the impact of barriers to energy efficiency vary by business activity [38,39,68,57].

4. Results

Table 5 and Table 6 show the outcomes of the logit regressions for both behaviour measures and fabric upgrade measures. The Odds Ratios (OR) and marginal probabilities discussed are from the models fitted to the raw survey data. Results from listwise deletion and imputation methods are mentioned where appropriate. The characteristics that influence the decision to investigate a fabric upgrade are presented first. A subsequent section deals with the factors found to influence decisions to investigate a behaviour change measure.

4.1. Fabric upgrade Logit model results

The nature of a company's tenure and the decision making responsibility of the survey respondent show a strong association with the likelihood of investigating a fabric upgrade measure. Companies that own the building they operate from and where the respondent is responsible for energy related decision-making are over 16 times more likely to engage with energy efficiency options.

Companies with more than 10 employees are found to be over 2.5 times more likely to investigate a fabric upgrade. The interaction of EMPLOYEES and OWNER is also significant in the model. Companies that rent their commercial space and that have more than 10 employees were significantly more likely to investigate the options as compared to tenant companies with less than 10 employees. No statistical difference in the likelihood of

[3] A multinomial logit with the dependent variable as M2=1 if the data is missing, M2 =0 if data report estimated over 20 imputations

investigation was found between those companies with more than 10 employees that own their building, and those that rent.

PAYBACK and BUDGET variables were both found to be significant in the model. Companies that implement a case-by-case approach to budgeting decisions are 1.5 times more likely to investigate a fabric upgrade. Companies that are willing to wait longer for the energy savings to cover the cost of investment are also significantly more likely to investigate a fabric measure.

Figure 3 shows how the interaction of payback expectations has a significant influence in this dynamic. The slope of the marginal probability for PAYBACK is significantly different across the combinations of TENURE and DECISION_MAKER. The marginal probability for companies who own their building and where the respondents are responsible for energy related decision makers does not vary as payback time increases; PAYBACK does not seem to influence the decision to investigate a fabric upgrade for this cohort. Overall this cohort is more likely than the other interaction categories to investigate a fabric upgrade at all payback levels.

For companies who own the building and where the respondent is not the decision maker, the likelihood of investigation increases for companies who accept longer paybacks. Tenants who are the energy efficiency decision makers have a similar slope to the latter category, with no statistical difference evident between the two categories. A counter intuitive outcome is evident for companies who are tenants and who are not responsible for energy related decisions, as the stated acceptable period of payback in years increases, this cohort becomes less likely to have investigated an energy efficiency upgrade. As more energy efficiency measures become economic with an increasing payback period, it could be expected that building occupants accepting higher payback periods would be more likely to investigate these opportunities. This is the case with the other cohorts presented in . It is unclear from the data what is driving this result but perhaps the distance of this cohort from financial and building related decisions leads to less considered responses.

The types of commercial activity undertaken in a building are significant and there are differences in likelihood found between some sectors. Figure 4 shows the marginal probabilities for each business activity. Offices and Hotels are most likely to have investigated an upgrade, with Warehouses and Retail companies least likely. These differences are statistically significant for Offices compared to Retail and to Warehouses and also for hotels compared to Warehouses, all at the 95% significance level.

Respondents who did not reply to the question on the floor area of the building are significantly less likely to have investigated a fabric upgrade. A listwise deletion of the ‘no reply’ cohort resulted in a change of magnitude and significance of a number of variables with the marginal probabilities of investigation increasing across most variables. Companies who owned their own building and where the respondent is the decision maker were over 30 times more likely to investigate a fabric upgrade. Furthermore, the likelihood for companies with more than 10 employees increased in the listwise model. The odds ratio for companies who have had a building renovation at some time over the past 10 years is 1.598 – lower than the results from the other models for the same variable shown in Table 5. In addition, previously significant categories in the ACTIVITY variable in the other models lose their significance in the listwise model. An examination of the no reply cohort using a separate logit equation showed some significant associations. No replies are more likely

from hotels, restaurants/public houses and offices, which have not renovated recently, use oil, gas or other as the primary heating fuel and who apply fixed budget rules to investment decisions. The logit results for this equation are shown in Table 7 in the appendix.

The RENOVATED variable was also found to be significant. Business operating from buildings that were renovated sometime in the previous 10 years is almost twice as likely to have investigated a fabric energy efficiency measure.

The underlying data set does include information on the energy use or costs faced by the companies surveyed. To try an estimate this impact, the initial model specification included an interaction term combing floor area, type of heating fuel and the number of employees as a proxy for energy use and energy costs. The interaction was not significant and did not impact on the significance of other terms in the model hence it was dropped from the final specification.

4.2. Behaviour change Logit model results

Analysis of the factors that influence a company to investigate a behaviour change measure differ somewhat from those factors that influence fabric upgrade. Similar to the fabric upgrade case, a lack of knowledge of the size of the building is a strong predictor of lack of engagement but the company business activity, the company's tenure in the building they operate from, the decision making responsibility of the respondent and the number of employees differ in their effect.

The interaction between ACTIVITY and BUDGET is significant for a number of business activities. Companies who make budget decisions on the basis of the individual business case of each measure, and who operate from office buildings or warehouses, are more likely than hotels, retail premises and restaurants/public houses to investigate behaviour change. Figure 5 summarises the marginal probabilities of the budget approaches across the business activities.

Office buildings with a case-by-case budgeting approach are over 2.6 times than office buildings that apply fixed budget rules of thumb to investment decisions to report investigating a behavioural measure. The same is true of warehouse and storage businesses. Office based businesses with a 'business case' approach have an 80% marginal probability of saying they have investigated a behaviour change as compared to a 59% - 73% probability range for retail, hotels and restaurants/public houses and a 59% probability for offices who uses fixed budget rules of thumb.

The answer respondents gave to the question on the size of the business premises was significant in explaining the likelihood of investigating a behaviour change energy efficiency measure. Those respondents who did not respond to the question on the size of the business premises were also significantly less likely to report having investigated a behaviour change. As described in the fabric upgrade results and shown in table 5 in the appendix, this cohort of business has a set of defining characteristics that sets them apart – hotels, restaurants/public houses and offices, who have not renovated recently, use oil, gas or other as the primary heating fuel and who apply fixed budget rules to investment decisions are less likely to respond to the floor area question.

The number of employees alone was not a significant indicator of the likelihood to investigate a behaviour change measure. When the interaction with floor area is considered, companies with more than 10 employees and with floor areas greater than 1,000 m^2 are significantly more likely to have investigated a behaviour change measure. This category is over 3 times more likely to have reported investigating behaviour change as compared to the base category: the cohort with less than 10 employees and a floor area of under 1,000 m^2.

The interaction of ELECTRICITY and DECISION_MAKER is significant in all models. Companies who use electricity as the main heating fuel and where the respondent to the survey was responsible for energy related decisions were about half as likely to have investigated a behaviour upgrade when compared to companies who use other fuels for heating and where the respondent in the decision maker. Companies units using oil, gas or other fuel sources and where the respondent was not responsible for energy related decisions were significantly less likely to investigate a behaviour change measure when compared to the base category.

Owning the building tends to favour engagement with a behaviour change investigation though is significant only in raw survey data model. The decision-making responsibility of the respondent did not have a significant association with behaviour change investigation. In contrast to the fabric upgrade model, the interaction of both variables is insignificant and was dropped from the final specification of the behaviour measure model.

Companies where the respondent is responsible for energy related decisions and where a business case approach is applied to budget decisions are between 2.4 times and 4.3 times more likely to have investigated a behaviour change. The marginal probabilities for companies where the respondent was not the decision maker and where a case by case budgeting approach is taken (pr 57%) showed no statistical difference in comparisons with companies where the a fixed budget approach was taken, (pr 60%).

Companies who occupy buildings that have been renovated or upgraded in the last 10 years were significantly more likely to have considered a behaviour change. When those respondents that did not reply to the floor area question were excluded the significance dropped below the 90% level.

5. Discussion:

In order for a company to undertake a measure they must first invest the time in investigating the options available. The representative survey data shows that almost half of Irish companies operating in the commercial sector do not take this first essential step in accessing the energy efficiency measures available to them. The findings presented identify the company factors that are associated with a likelihood of investigating an energy efficiency measure. This section reflects on the findings of this paper in the context of other empirical analyses and mentions the theoretical background where relevant.

The influence of tenure and localised energy related decision-making responsibilities are perhaps the most definitive insight from our analysis. Companies who own the building they operate from and where energy related decisions are made by local management are found to be much more likely to investigate a fabric upgrade measure. These findings are consistent with the split incentive barrier and organisational barriers identified in the theoretical literature on barriers. Our findings may tentatively indicate that energy efficiency

drivers may also be influencing companies, with these favourable characteristics. The literature that explores the drivers for energy efficiency cites improved working environments, greater comfort levels, increase asset values and productivity as reasons for companies to take up these measures.

The empirical studies we have reviewed did not examine the interaction of tenure with energy related decision-making responsibility as we have here. Some empirical literature has examined the impact of renting on uptake while other studies have looked at the impact of internal investment decision processes. Schleich and Gruber [38] and Schleich [61] found that renting commercial space was a barrier to organisations in over half the sub-sectors they examined. Fleiter et al.,[62] examined the impact of tenure on uptake and found no significant relationship. They hypothesise that the provision of information through building energy ratings may have mitigated the impact of this and other barriers identified elsewhere in the literature [62]. Muthulingam et al., [63] found that managerial attention requirements influence the adoption rate of energy efficiency measures. Trianni and Cagno [39] and Thollander et al., [53] identify lack of access to internal capital as a barrier. While the control variables used in these studies are not directly comparable to the decision-making responsibility variable used here, they do support the finding that the investment decision process can present organisational barriers to energy efficiency measures.

Companies with more than 10 employees are found to be more likely to investigate both fabric upgrades and behavioural options. This finding is consistent with several other empirical studies including Anderson and Newell [50], Aramyan et al.,[60], and Schleich [61]. Some studies that have included variables representing the number of employees, have not found a significant relationship with likelihood to take up an energy efficiency measure; Fleiter et al.,[62] postulate that the effect maybe captured in other control variables included in the model. Several of the analyses report lack of time to investigate measures as an important factor [19,37,39,52,53]. The data our analysis relies on does not allow for the inclusion of a control variable for lack of time, though it is probable that the effect maybe captured by the variable we include on number of employees. Analysis by Velthuijsen [68] (reported in [62]) finds an additional nuance: as the size of a firm increases decision making complexity begins to negatively impact on uptake. Commercial sector companies of 100 employees or more are rare in Ireland. This may partially explain why no such negative relationship was found in our analysis.

Our analysis found that companies who did not provide a response to the question on floor area were less likely to investigate a fabric upgrade or a behavioural measure. Lacking basic information, like floor area and energy use, has been found to negatively impact the uptake on energy efficiency measures[38,52,56,61,69]. Some empirical analyses have shown how information campaigns and energy audits can remove the impact of information barriers [50,51,53,62]. For example, Fletier et al., [62] examined the uptake of measures in the German SMEs after an energy audit was completed and the firm was provided with information on energy saving options. They found that lack of information was not a significant variable for these companies [62]. In our analysis, companies who had undergone some form of a renovation in the previous 10 years were more likely to have investigated a fabric upgrade. This may suggest a similar effect. It is interesting to note, that having undergone a renovation, companies were also more likely to have investigated a behaviour change measure. Cagno et al., [40] review of the literature on barriers to industrial energy efficiency explains the role of building designers, building contractors and trusted

independent third parties in disseminating information on energy saving measures. The energy agency in Ireland (SEAI) has been active in providing information as well as mentoring in the past decade and runs a tax rebate scheme for companies that install equipment listed as highly energy efficient. The energy agency and wider market activity maybe helping companies to access information on energy efficiency as part of the renovation process.

The empirical evidence shows that lack of capital, both internally within the company, and from external sources, are significant barriers to the uptake of energy efficiency measures [39,50,53,54,56,62,63,68]. Our findings expand on this and examine the impact of bounded rationality in budgeting decisions. Our analysis found that the use of heuristics – through the application of budget expenditure limits – was associated with a lower likelihood of investigating fabric upgrade options. The approach to budget decisions also had some impact on the likelihood of investigating a behavioural measure when the interaction with decision-making responsibility and commercial activity were considered.

The payback duration required was also found to be significant. Companies that accept longer payback times were found to be more likely to investigate fabric upgrade measures. This agrees with Harris et al.,[51] Diederen et al.,[59] and, Anderson and Newell [50]who found payback and hurdle rates to be relevant to the uptake of energy efficiency measures. The findings on budget approach and payback lengths are notable given that little or no capital commitment is required to investigate a measure but yet those companies with budget limits and short payback requirements are less likely to investigate energy saving options. This may reflect organisational barriers or a focus of investment options related to core business only.

The various sub-sectoral business activities undertaken in a building has a significant association with the likelihood of having investigated a fabric upgrade measure. Offices and hotels were found to be more likely to have considered such options as compared to retail and warehouse/storage. De Canio [36] examined the influence of variables including sub-sectoral classification on the profitability of lighting upgrade projects and found that the type of business activity is significant. de Groot et al., [58] and Schleich [61] examined barriers at a sub-sector level for German and Dutch data sets respectively. They found differences in the significance and magnitude of barriers within the sub-sectors. These broadly align with our findings and may hint that individual sub-sectors respond to the drivers in different ways. It is plausible that hotels and offices may value the co-benefits from upgrade measures, such as increase internal comfort and noise reduction, more than retail or warehouse sub-sectors.

The underlying data set for our analysis did not have information on energy bills. A proxy for energy costs was examined through the interaction of building size, number of employees and heating fuel type but was not found to be significant in the decision to investigate. The empirical findings differ on this point. Some studies have not found a significant link between energy costs and the uptake of energy efficiency measures while others found that the share of energy costs in total operating costs has been found to influence upgrade activity in a number of empirical studies. Schleich [61] found that a higher annual energy use per employee to positively influence the likelihood of an organisation investigating and implementing a measure. Anderson and Newell [50] found that increases in energy costs increased the likelihood of a measure being implemented in manufacturing plants. In contrast, de Groot et al[58], found no significant relationship between companies'

prioritisation of energy and the uptake of energy efficient measures [58]. Similarly, Fleiter et al. [62] find no significant relationship between the variable capturing energy costs and likelihood of uptake. Our findings should be viewed in the context that energy use is a relatively minor cost for the majority of commercial sector companies in Ireland. In addition, as table 3 shows the low priority of reducing energy use reported over 77% of those respondents as the reason for not investigating an upgrade.

6. Conclusion

This paper examines the factors that are associated with the likelihood that a commercial sector company will investigate a fabric upgrade or investigate a behaviour change energy efficiency measure. The analysis is based on an internationally rare example of statistically representative data set for the commercial sector in Ireland. The data set is complied from a survey of commercial sector business units and captures building specific and company specific characteristics as well as their behaviours and attitudes towards energy efficiency.

The profile of companies were represented in the regression models by the type of commercial activity undertaken in the building, the number of employees normally at work at the premises on typical day, the floor area of the building, the fuel used for heating, if the building is owned or rented, and if energy related investment decisions are made locally. Factors representing the companies approach to determining capital expenditure budgets and their acceptable payback lengths were also included. Two Logit models were specified separately to examine the influence these factors have on decisions to investigate a fabric upgrade measure, and a behaviour change measure.

Our results show that companies who rent the building they occupy and where decision-making responsibilities are not made locally are unlikely to investigate a fabric upgrade measure suggesting that spit incentives and organisational barriers are acting to prevent engagement for this cohort. Hotels and offices were significantly more likely to have investigated a measure relative to companies in retail and warehouse sub-sectors, perhaps suggesting that some additional energy efficiency drivers are promoting engagement in these sectors. Lack of time, internal expertise and the hassle of investigating the available options have been reported as barriers to energy efficiency in the literature. Our results also show larger companies with more than 10 employees were more likely to have investigated a fabric upgrade measure.

Lack of information on energy use and on the intervention measures available are frequently identified in the literature as preventing adoption of measures. Our results resonate with this, with respondents that did not know the floor area of their business premises significantly less likely to investigate upgrade options. In addition, our results show that companies that recently had a renovation were more likely to have investigated a fabric upgrade measure, perhaps due to the availability of accessible information during this process. Companies that apply a fixed limit budgeting approach and that have short payback requirements stand less likely to engage with fabric upgrades options. This is an interesting finding given that relatively little budget commitment is required to investigate the available measures.

Companies with more employees, larger floor areas, that own their own building, operate as offices or warehouses and who apply a business case evaluation for each individual project were more likely to investigate behaviour change measures. Interestingly, those companies

who had a recent renovation were also more likely to have investigated a behaviour change, suggesting that the information and awareness of the building can motivate wider interest in energy savings. Respondents who did not report floor area, were not the energy decision makers and who use electricity as a heating source where less likely to investigate behaviour change measures.

Our findings are consistent with the previous empirical and theoretical literature on the barriers and drivers to energy efficiency. Much of the previous research is concerned with the final adoption of measures; our analysis adds additional insights by identifying the factors that determine if a company is likely to investigate the options available. The focus of previous research has been on the adoption of appliance and fabric upgrade options; we also contribute additional information by extending the analysis to identify factors that influence the decision to investigate behaviour change options. The robustness of the statistically representative data set underlying the analysis is also a useful and rare aspect of this work.

This paper examines the barriers and drivers across the decision making process by focusing on the first step in the process of implementing a saving measure, the investigation step. Further research that separates the effect of barriers at the investigation step from their effect at the implementation phase would add an additional layer of understanding into how the barriers act to impede energy savings uptake at the various stages of the decision making process. Our initial model specification looked at examining the adoption of measures by first controlling for the self-selection bias of companies who investigated measures but the data set did not support this two-stage analysis. Future data collection efforts can keep the usefulness of these staged approaches in mind during survey design.

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8. Appendix:

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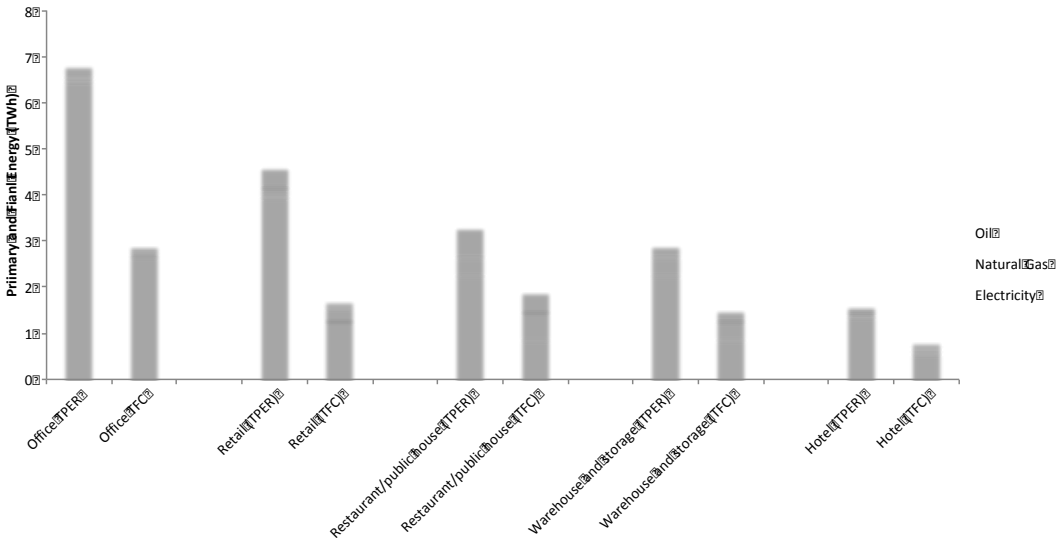
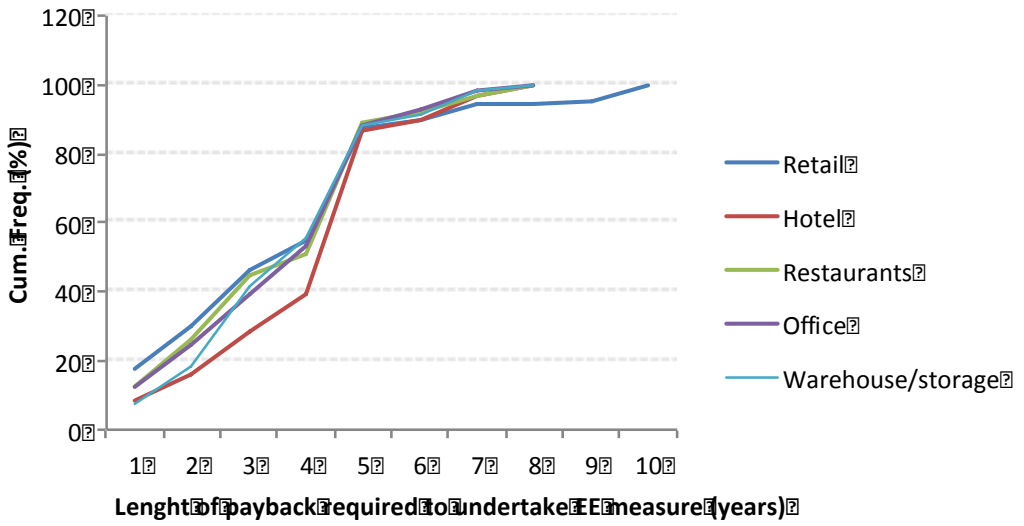


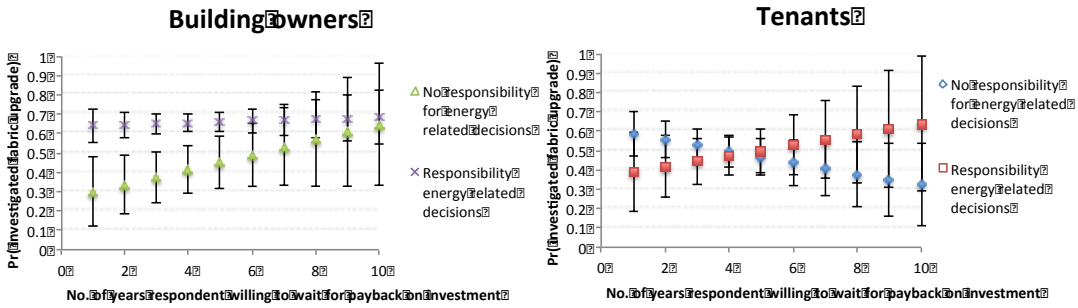
<InlineImage1>

Figure 1: Primary and final energy in the Irish commercial sector by building activity. [65]



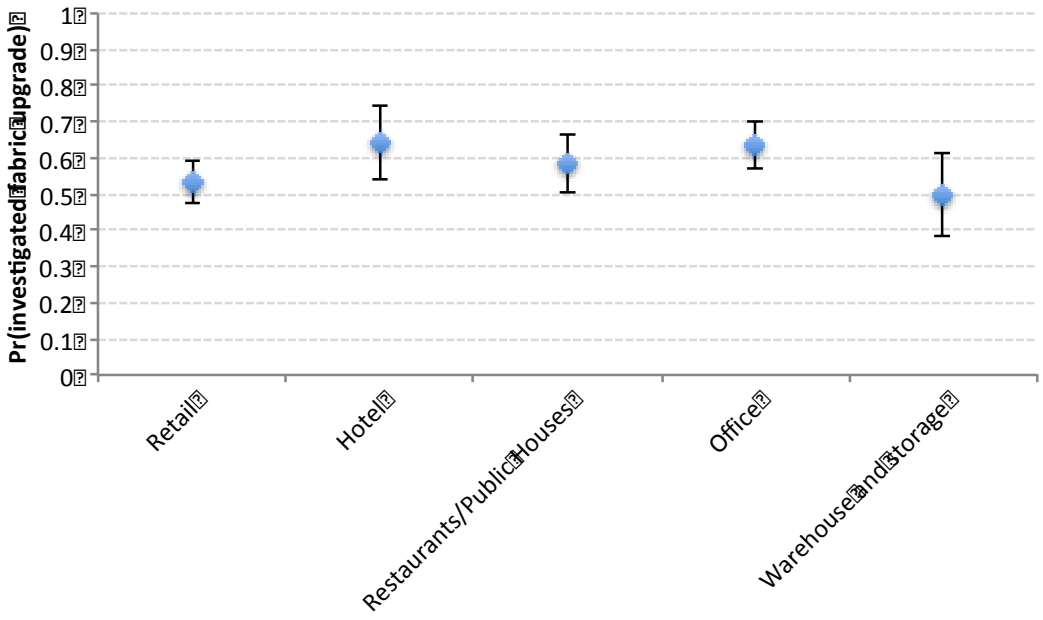
<InlineImage2>

Figure 2: Maximum time an energy efficiency measure must payback in; by business activity



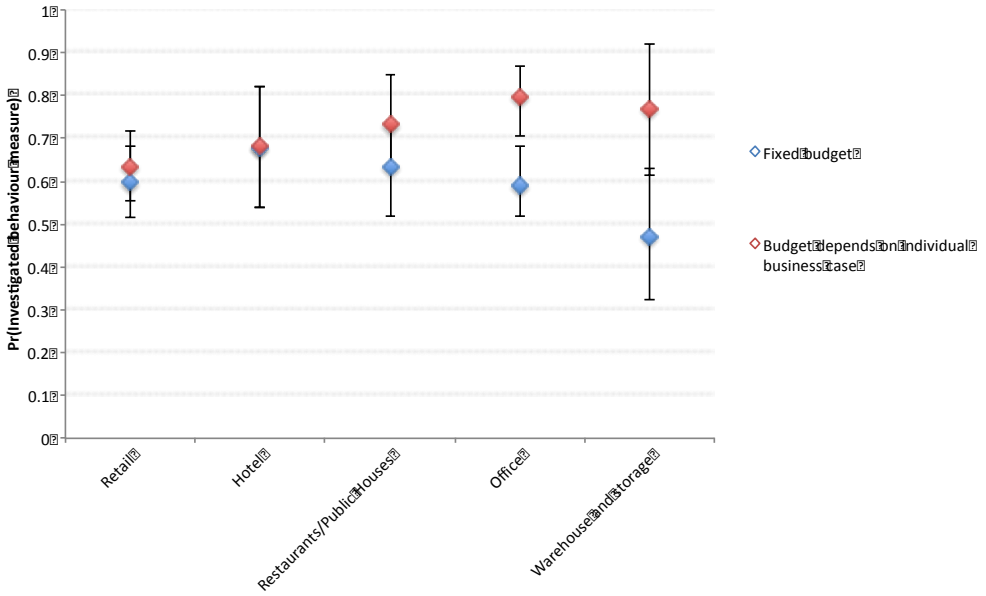
<InlineImage3>

Figure 3: Marginal probability of fabric investigation at each year of acceptable PAYBACK by tenure and by decision-making responsibility of the respondent.



<InlineImage4>

Figure 4: Marginal probabilities by company ACTIVITY of investigating a fabric upgrade (95% interval)



<InlineImage5>

Figure 5: Marginal probabilities by company ACTIVITY and BUDGET approach of investigating a fabric upgrade (95% interval)

	Office	Retail	Restaurant/Public house	Warehouse/ storage	Hotel
No. of Buildings (,000)	42	40	16	8	4

Table 1: Number of buildings by commercial activity

	Total (n=750)		**Retail (n-255)**	**Hotel (n=95)**	**Restaurants/ Pubs**	**Office (n=194)**	**Warehouse (n=70)**

						(n=136)		
Number of employees	≤10	66%		73%	38%	72%	66%	66%
	>10	34%		27%	62%	28%	34%	34%
Tenure type	Owner	67%		62%	85%	80%	52%	73%
	Tennant	33%		38%	15%	20%	48%	27%
Respondent status in energy related decisions	Decision maker	70%		64%	96%	82%	57%	70%
	Not a decision maker	30%		36%	4%	18%	43%	30%
Budgeting approach	<€10,000	49%		50%	32%	54%	49%	56%
	≥€10,000	6%		4%	19%	4%	5%	4%
	Depends on business case of individual measure	45%		46%	49%	41%	46%	40%
Floor area	< 1,000 m2	38%		44%	17%	38%	41%	33%
	≥ 1,000 m2	23%		25%	28%	13%	19%	34%
	No Reply	40%		31%	55%	49%	40%	33%
Recently renovated	Yes	17%		14%	38%	15%	17%	9%
	No	83%		86%	62%	85%	83%	91%
Heating fuel type	Electricity	44%		58%	20%	26%	53%	33%
	Gas, Oil or Other	56%		42%	80%	74%	47%	67%
Investigated fabric upgrade	Did not investigate	42%		50%	28%	39%	37%	53%
	Investigated but did nothing	7%		7%	5%	10%	6%	4%
	Investigated, took action but think more to do	21%		18%	29%	23%	23%	17%
	Investigated, took action, think no more to do	30%		26%	37%	29%	35%	26%
Investigated behaviour measure	Did not investigate	35%		41%	22%	33%	35%	40%
	Investigated but did nothing	6%		7%	7%	4%	7%	4%
	Investigated, took action but think more to do	31%		26%	39%	36%	30%	30%
	Investigated, took action, think no more to do	28%		26%	32%	27%	29%	26%

Table 2: Summary of survey data by variable and by business activity

	Retail	Hotel	Public Houses and Restaurants	Offices	Warehouse and storage	Total
Behaviour						
Sceptical that reductions in energy use through behavioural change are possible	13%	10%	9%	6%	7%	10%
Reducing energy use is not a top priority	69%	81%	71%	73%	75%	72%
Planning to investigate	6%	0%	4%	9%	0%	5%
Need more information on possible measures	12%	10%	16%	12%	18%	13%
Fabric Upgrade						

Sceptical that reductions in energy use through fabric upgrades are possible	5%	11%	8%	4%	3%	5%
Reducing energy use is not a top priority	79%	70%	75%	73%	86%	77%
Planning to investigate	5%	4%	4%	3%	3%	4%
Need more information on possible measures	5%	0%	6%	15%	3%	7%
Fabric improvements are not responsibility of occupant	7%	15%	8%	4%	5%	7%

Table 3: Reasons given for not investigating energy efficiency upgrade, number of responses

Table 4: Information collected in commercial sector attitudes survey

	Variable	Freq.	Mean	Std. Dev.	Min	Max	Description
BEHAVIOUR	Organisation investigated behaviour change measure	750	0.647	0.478	0	1	1= The organisation has investigated ways to reduce energy use through behaviour change
FABRIC	Organisation investigated fabric upgrade measure	750	0.580	0.494	0	1	1 = The organisation has investigated ways to reduce energy use through improving the building fabric
BUDGET	Budgeting rules	750	0.451	0.498	0	1	0= Fixed budget for energy efficiency investments, 1= No fixed budget – it would depend on the business case for the measure
ELECTRICITY	Primary heating source	750	0.436	0.496	0	1	0= Oil or gas, LNG, solid fuel or wood chips is the primary means of heating the building 1= Electricity is the primary means of heating the building,
EMPLOYEES	No. of Employees	750	0.343	0.475	0	1	1= More than 10 employees
RENOVATED	Building renovated in the last 10 years	750	0.656	0.475	0	1	1= Premises has undergone maintenance, renovation, fit out or upgrade of the fuel system in the last 10 years
OWNER	Organisation owns the building	750	0.667	0.472	0	1	0 = Organisation is a tenant in the building 1= Organisation owns the building
DECISION_MAKER	Respondent is decision maker for energy related decisions in the building	750	0.701	0.458	0	1	1= Respondent is responsible for energy related decisions
PAYBACK	Payback requirements	750	3.997	2.003	1	10	The maximum number of years an organisation is willing to wait for the savings to cover the investment costs
ACTIVITY	Business activity undertaken in the building	750					The primary business activity undertaken in the building
	Retail	*255*					
	Hotel	*95*					

	Public Houses and Restaurants	*136*	
	Offices	*194*	
	Warehouse and storage	*70*	
M2	Floor area	750	The floor area taken up by an organisation in the building
	Small: < 1,000 M2 floor area	*282*	
	Large: > 1,000 M2 floor area	*169*	
	No Reply	*299*	

Investigated fabric upgrade		**Survey Data**	**Listwise deletion**	**Multiple Imputation**
	(Robust se)	**n=750**	**n=451**	**n=750**
ACTIVITY	Hotels	1.638*	1.610	1.530
		(0.484)	(0.714)	(0.450)
	Restaurants/ Public houses	1.241	0.878	1.172
		(0.302)	(0.280)	(0.281)
	Office	1.605**	1.460	1.552**
		(0.346)	(0.396)	(0.334)
	Warehouse and storage	0.848	0.791	0.859
		(0.244)	(0.287)	(0.248)
EMPLOYEES	> 10 employees	2.796***	3.314***	2.662***
		(0.876)	(1.446)	(0.859)
BUDGET	No fixed budget – it would depend on the business case for the measure	1.513**	1.461*	1.429**
		(0.255)	(0.323)	(0.235)
M2	Large (> 1,000 m2)	0.895	0.917	0.931
		(0.202)	(0.217)	(0.195)
	No Reply	0.661**		
		(0.126)		
RENOVATED	Some building upgrade in the last 10 years	1.900***	1.598**	1.971***
		(0.327)	(0.370)	(0.341)
ELECTRICITY	Uses electricity for heat	1.073	0.938	1.108
		(0.189)	(0.210)	(0.194)
OWNER	Business owns the building	0.309*	0.197**	0.286**
		(0.192)	(0.152)	(0.177)
DECISION_MAKER	Respondent is responsible for energy related decisions	0.316*	0.189*	0.295*
		(0.221)	(0.179)	(0.204)
OWNER X DECISION _MAKER		16.321***	33.106***	17.984***
		(14.906)	(39.449)	(16.239)
PAYBACK	Minimum payback requirement	0.873*	0.847*	0.872*
		(0.063)	(0.084)	(0.063)
OWNER X EMPLOYEES		0.306***	0.184***	0.321***
		(0.114)	(0.094)	(0.120)
OWNER X DECIOSN_MAKER X PAYBACK	Owner and responsible for energy related decisions	1.171*	1.246*	1.173*
		(0.106)	(0.159)	(0.107)
	Owner and not responsible for energy related decisions	1.356**	1.349*	1.375**
		(0.184)	(0.218)	(0.187)
	Tennant and responsible for energy related decisions	1.299*	1.425*	1.322*
		(0.202)	(0.295)	(0.203)
Constant		0.618	1.034	0.553
		(0.243)	(0.517)	(0.213)

Significant at *90%, **95%,***99%

Table 5: Logit regression with odds ratios of likelihood of having investigated a fabric upgrade

Table 6: Logit odds ratios for likelihood of a company investigating a behaviour change

Table 7: Results of logit regression on likelihood of company to not provide a response to question on floor area

Did not reply to Q on floor area =1

		(Robust se)	**n=750**	**Odds ratio**
ACTIVITY	Hotels			2.479***
				(0.678)
	Restaurants/ Public houses			2.000***

Investigated behaviour change			Untreated Data	Listwise deletion	Multiple Imputation
		(Robust se)	n=750	n-451	n=750
ACTIVITY	Hotels		1.462	1.147	1.234
			(0.605)	(0.640)	(0.305)
	Restaurants/ Public houses		1.183	1.842	1.008
			(0.356)	(0.795)	(0.308)
BUDGET	Office	No fixed budget – it would depend on the business case for the measure	0.961	0.877	0.896
			(0.271)	(0.297)	(0.249)
EMPLOYEES	Warehouse and storage	> 10 employees	0.572	0.415*	1.041
			(0.226)	(0.192)	(0.222)
ELECTRICITY		Uses electricity for heat	0.653	0.423*	0.560
			(0.241)	(0.198)	(0.204)
DECISION_MAKER		Respondent is responsible for energy related decisions	0.875	0.438	0.902
			(0.505)	(0.347)	(0.513)
OWNER		Company owns the building	1.421	0.346	1.530
			(0.701)	(0.246)	(0.739)
RENOVATED		Some building upgrade in the last 10 years	2.644**	3.105**	2.731**
			(1.142)	(1.784)	(1.177)
DECIOSN_MAKER X OWNER			3.714**	8.180**	3.683**
			(2.432)	(7.544)	(2.390)
ELECTRICITY X EMPLOYEES			0.923	0.878	1.020
			(0.265)	(0.258)	(0.278)
M2	Large (> 1,000 m2)		0.486***		0.687
			(0.108)		(0.238)
Constant	No Reply		[0.107]		

Significant at *90%, **95%,***99%

EMPLOYEES	> 10 employees	1.040	1.049	1.382
		(0.378)	(0.392)	(0.429)
EMPLOYEES X M2	> 10 employees X Large (>1,000 m2)	3.053**	3.455**	1.958
		(1.606)	(1.871)	(0.900)
	> 10 employees X No Reply	2.454**		
		(1.121)		
ELECTRICITY	Uses electricity for heat	1.582	1.749	1.666*
		(0.478)	(0.696)	(0.493)
DECISION_MAKER	Respondent is responsible for energy related decisions	1.615	1.597	1.530
		(0.533)	(0.682)	(0.503)
ELECTRICTY X DECISION_MAKER		0.468**	0.433*	0.471**
		(0.172)	(0.211)	(0.170)
RENOVATED	Some building upgrade in the last 10 years	1.455**	1.420	1.557**
		(0.259)	(0.352)	(0.275)
BUDGET X DECIOSN_MAKER		2.442**	4.353***	2.513**
		(0.925)	(2.211)	(0.943)
OWNER	Business owns the building	1.426*	1.432	1.375
		(0.291)	(0.382)	(0.275)
Constant		0.687	0.767	0.569*
		(0.238)	(0.328)	(0.195)

Significant at *90%, **95%,***99%